



Work-Related Asthma in Korea – Findings from the Korea Work-Related Asthma Surveillance (KOWAS) program, 2004–2009

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Purpose: To determine the incidence and epidemiological characteristics of work-related asthma in Korea. **Methods:** During 2004-2009, the Korea Work-Related Asthma Surveillance (KOWAS) program collected data on new cases of work-related asthma from occupational physicians, allergy and chest physicians, regional surveillance systems, and workers' compensation schemes. The incidence was calculated on the basis of industry, occupation, sex, age, and region. In addition, the distribution of causal agents was determined. **Results:** During the study period, 236 cases of work-related asthma were reported, with 77 cases from more than 1 source. A total of 22.0% (n=52) were reported by occupational physicians, 52.5% (n=124) by allergy and chest physicians, 24.2% (n=57) by regional surveillance systems, and 43.2% (n=102) by workers' compensation schemes. The overall average annual incidence was 3.31 cases/million workers, with a rate of 3.78/million among men and 2.58/million among women. The highest incidence was observed in the 50-59-year age group (7.74/million), in the Gyeonggi/Incheon suburb of Seoul (8.50/million), in the furniture and other instrument manufacturing industries (67.62/million), and among craft and related trades workers (17.75/million). The most common causal agents were isocyanates (46.6%), flour/grain (8.5%), metal (5.9%), reactive dyes (5.1%), and solvents (4.2%). **Conclusions:** The incidence of work-related asthma in Korea was relatively low, and varied according to industry, occupation, gender, age, and region. Data provided by workers' compensation schemes and physician reports have been useful for determining the incidence and causes of work-related asthma.

Key Words: Work-related asthma; incidence; surveillance; industry; occupation

INTRODUCTION

Asthma is a common chronic disease, affecting at least 300 million people worldwide.¹ It can develop at any age and is known to be associated with genetic, environmental, nutritional, and socioeconomic factors.^{2,3} Some known risk factors for adult-onset asthma are female sex, atopy, nasal allergy, family history, and high-risk occupations.^{4,5} The population-attributable risk for adult asthma due to occupational exposure is thought to be 10%-25%.⁵

Work-related asthma (WRA) refers to the exacerbation of pre-existing or concurrent asthma in the workplace, as well as to new-onset asthma induced by sensitizers or irritants present in the workplace.⁶ It is the most common work-related respiratory disease in industrialized countries,^{7,8} and the second most common in Korea after pneumoconiosis.⁹

The first case of WRA in Korea was identified in a sea squirt processing factory in 1976.¹⁰ Many more cases and causal agents

have been reported since, with isocyanates and reactive dyes being the most common agents.¹¹⁻¹³ Before the Korea Work-Related Asthma Surveillance (KOWAS) program began in 2004, apart from a temporary WRA surveillance program conducted for 1 year in 1998, the only method to systematically estimate the number of WRA cases in Korea was by extracting data from workers' compensation schemes.¹⁴ This report provides findings from the first 6 years of the KOWAS program (2004-2009). We used KOWAS data to estimate the incidence of WRA by examining various demographic factors and to identify the distribution of causal agents over the study period.

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MATERIALS AND METHODS

The establishment of KOWAS

KOWAS is a scheme designed to collect information on WRA cases from multiple reporting sources. It was set up in 2004 by the Occupational Safety and Health Research Institute of the Korea Occupational Safety and Health Agency (OSHRI-KO-SHA). The Department of Occupational and Environmental Medicine of Hanyang University was selected as the KOWAS program's headquarters.

The scheme's reporting sources include the Korea Workers' Compensation and Welfare Service, occupational physicians, allergy and chest physicians, and regional work-related disease surveillance systems (*i.e.* regional surveillance systems that are housed in universities and funded by the KOSHA¹⁵). At the start of the program, there were 42 participating allergy and chest physicians, most of whom were affiliated with university hospitals. There were also 30 participating occupational health physicians or institutions, which included members of the Korean Association of Occupational and Environmental Clinics (KOEK). Regional surveillance systems located in the cities of Gumi, Incheon, Busan, and Changwon participated in the scheme in 2004, but from 2005 to 2007, only the systems in Incheon and Busan continued their participation. None of the regional surveillance systems participated after 2007.

Reporting individual cases

Individual patients were written up as case reports and sent to the KOWAS program headquarters. Each case report included the patient's sex, age, geographic location, occupation type, and exposure duration. In addition, the suspected causal agent, dates of asthma onset and diagnosis, whether it was new-onset versus exacerbation of preexisting asthma, and whether objective diagnostic tests had been conducted were also reported.

Definitions

There are 2 sub-types of WRA: (1) work-exacerbated asthma (WEA) and (2) new-onset occupational asthma (OA). New-onset OA is further divided into sensitizer-induced OA and irritant-induced OA, including reactive airways dysfunction syndrome (RADS).¹⁶ The definition of WRA proposed by the National Institute for Occupational Safety and Health (NIOSH) was used in our study.¹⁷ Thus, all WRA cases satisfied criteria (A) and (B) listed below. In addition, all cases satisfied 1 or more of the following criteria: (A) Diagnosis of asthma by a physician, (B) An association between the symptoms of asthma and work, (1) Workplace exposure to an agent or process previously associated with WRA, (2) Significant work-related changes in forced expiratory volume in 1 second (FEV1) or peak expiratory flow rate (PEFR), (3) Significant work-related changes in airways responsiveness measured by a nonspecific inhalation challenge test, (4) A positive response to an inhalation challenge test with

a specific agent to which the individual is exposed at work.

The work-relatedness of WRA was classified as "definite" (satisfied the following elements of the case definition: A, B, 1, plus ≥ 2 of criteria 2-4), "probable" (A, B, 1, plus 1 of criteria 2-4), "possible" (A, B, did not satisfy 1 but satisfied ≥ 1 of criteria 2-4), and "suspicious" (A and B only) by the reporting source.^{13,18}

Statistical analysis

The average annual incidence of WRA with regard to sex, age, region, industry, and occupation was based on the size of the working population as estimated in 2006 by the Korean Ministry of Employment and Labor,^{19,20} and 95% confidence intervals (CIs) were based on Poisson distribution. Industries and occupations were classified using the eighth Korean Standard Industrial Classification (KSIC),²¹ and the fifth Korean Standard Classification of Occupations (KSCO),²² respectively.

Capture-recapture analysis was used to obtain a nearly unbiased estimator (NUE) of the total number of WRA cases.²³ To do this, the 4 reporting sources were stratified into 2 categories as follows: (1) the workers' compensation scheme (*i.e.* the Korea Workers' Compensation and Welfare Service), and (2) the other 3 reporting sources (*i.e.* physicians' reports). Capture-recapture analysis was performed on specific industries and occupations when the number of overlapping reports was ≥ 7 . Overlapping reports, *i.e.* duplicate cases, were defined as individuals who had identical names, dates of birth, resident registration numbers, and employers found in both reporting categories.

The distribution of WRA cases based on sex, causal agent, WRA subtype, and reporting source were described over the study period, and annual trends were tested using the Cochran-Armitage test for trend. SAS 9.1 (SAS Institute Inc., Cary, NC, USA) was used to perform all statistical analyses.

RESULTS

From 2004 to 2009, a total of 239 cases of WRA were reported to the KOWAS, but 3 cases were excluded from analyses because the workplaces associated with these cases were not included in the working population in this study. A total of 236 cases were reported by 4 reporting sources: 52 (22.0%) by occupational physicians, 124 (52.5%) by allergy and chest physicians, 102 (43.2%) by workers' compensation schemes, and 57 (24.2%) by regional surveillance systems. Although some cases were reported multiple times by different sources and in different years, each individual was counted only once. A total of 164 (69.5%) cases were men, and 72 (30.5%) were women. The overall mean age was 44.1 (± 11.0) years, and the mean age for men (43.4 ± 11.5 years) and women (45.6 ± 9.5 years) were not significantly different. The highest frequencies of WRA were found among the 40-49 and 50-59-year-olds (31.4% and 26.3%, respectively). WRA was determined as "definite" in 58.1% of all cases ($n = 137$), "probable" in 36.4% ($n = 86$), "possible" in 4.2% ($n = 10$), and

“suspicious” in 1.3% (n=3). According to the WRA sub-types, new-onset asthma was most frequent (92.4%, n=218) with sensitizer-induced OA responsible for the vast majority at 86.9% of the total number of cases (n=205), followed by irritant-induced OA at 5.5% (n=13). WEA was responsible for 3.8% (n=9) of WRA cases. KOWAS had information regarding the specific objective tests that met the work-relatedness criteria for only 81 cases. Among these cases, 13 (16.0%) had work-related serial changes of PEFr or FEV1, 3 (3.7%) had work-related serial changes of nonspecific challenge tests, and 72 (88.9%) had a positive response to specific challenge tests. Objective tests were performed on the other 152 cases which were classified as

Table 1. Characteristics of work-related asthma cases - Korea, 2004-2009

	Cases n (%)	Age, Mean ± SD
Study population	236 (100.0)	44.1 ± 11.0
Sex		
Male	164 (69.5)	43.4 ± 11.5
Female	72 (30.5)	45.6 ± 9.5
Age (years)		
20-29	30 (12.7)	
30-39	52 (22.0)	
40-49	74 (31.4)	
50-59	62 (26.3)	
≥60	18 (7.6)	
Reporting source*		
Compensation scheme	102 (43.2)	
Allergy/chest physician	124 (52.5)	
Regional surveillance	57 (24.2)	
Occupational physician	52 (22.0)	
Work-relatedness		
Definite	137 (58.1)	
Probable	86 (36.4)	
Possible	10 (4.2)	
Suspicious	3 (1.3)	
WRA sub-types		
Sensitizer-induced asthma	205 (86.9)	
Irritant-induced asthma	13 (5.5)	
Work exacerbated asthma	9 (3.8)	
Unknown	9 (3.8)	
Objective test		
Nonspecific challenge test	110 (46.6)	
Work-related change in PEFr or FEV1	13 (5.5)	
Work-related change in nonspecific challenge test	3 (1.3)	
Specific challenge test	72 (30.5)	

*Total percentages may exceed 100 because of multiple reporting. WRA, work-related asthma; PEFr, peak expiratory flow rate; FEV1, forced expiratory volume in one second.

Table 2. Distribution of physician reported and work-related asthma cases by institution - Korea, 2004-2009

	Number of reporting physicians	Cases	Percent of cases	cumulative percent of cases
Allergy/chest clinic	28*	124 [†]		
Inha University hospital	1	32	25.4	25.4
Ajou University hospital	8	27	21.4	46.8
Soonchunhyang Buceon hospital	1	23	18.3	65.1
Chonnam University hospital	2	11	8.7	73.8
Sevrance hospital	2	9	7.1	81.0
Seoul National University hospital	7	7	5.6	86.5
Wonju Sevrance Christian hospital	2	5	4.0	90.5
Dankook University hospital	1	4	3.2	93.7
Kangdong Sacred Heart hospital	1	1	0.8	94.4
Korea University Guro hospital	1	1	0.8	95.2
Hanyang University hospital	1	1	0.8	96.0
Eulji hospital	1	1	0.8	96.8
Eulji University hospital	1	1	0.8	97.6
Bundang Jesaeng hospital	1	1	0.8	98.4
Seoul National University Bundang hospital	1	1	0.8	99.2
Ulsan University hospital	1	1	0.8	100.0
Occupational clinic	22 [‡]	52		
Hallym University Sacred Heart hospital	1	12	23.1	23.1
Inha University hospital	5	8	15.4	38.5
Dankook University hospital	1	5	9.6	48.1
Busan University hospital	1	4	7.7	55.8
Donga University hospital	2	3	5.8	61.5
Kosin University Gospel hospital	1	3	5.8	67.3
Eulji University hospital	2	3	5.8	73.1
Chonnam National University hospital	1	3	5.8	78.8
Yeouido St. Mary's hospital	2	2	3.8	82.7
Hanyang University hospital	2	2	3.8	86.5
Samsung Changwon hospital	1	2	3.8	90.4
Occupational Lung Disease Institute	1	2	3.8	94.2
Ulsan University hospital	1	1	1.9	96.2
Gumi Cha hospital	1	1	1.9	98.1
Soonchunhyang Gumi hospital	1	1	1.9	100.0
Regional surveillance system	13	57		
Incheon: Inha University ('04-'07)	5	43	75.4	75.4
Busan: Busan University ('04-'07)	4	10	17.5	93.0
Gumi: Cha University ('04)	2	2	3.5	96.5
Changwon: Sungkyunkwan University ('04)	1	2	3.5	100.0

*The sum of physicians exceeds 28 because 4 physicians were employed by more than one hospital during the study period; [†]The sum of cases exceeds 124 because 2 cases was reported by more than one hospital; [‡]The sum of reported physicians exceeds 22 because one physician was employed by more than one hospital during the study period.

Table 3. Crude and estimated average annual incidence of work-related asthma per million workers by age, sex, and region - Korea, 2004-2009

	Total cases n (%)	Workers' compensation reports	Physician reports*	Estimated cases [†] (95% CI)	Number of employees	Crude average annual incidence rate (95% CI)	Estimated average annual incidence rate [‡] (95% CI)
Study population	236 (100.0)	102	173	447 (353-541)	11,869,493	3.31 (2.90-3.76)	6.28 (4.96-7.60)
Sex							
Male	164 (69.5)	70	119	327 (240-414)	7,222,741	3.78 (3.23-4.41)	7.54 (5.53-9.55)
Female	72 (30.5)	32	54	120 (83-157)	4,646,752	2.58 (2.02-3.25)	4.30 (2.96-5.64)
Age (years)							
20-29	30 (12.7)				3,115,400	1.60 (1.08-2.29)	
30-39	52 (22.0)				4,054,890	2.14 (1.60-2.80)	
40-49	74 (31.4)				2,860,694	4.31 (3.39-5.41)	
50-59	62 (26.3)				1,334,595	7.74 (6.16-10.21)	
≥60	18 (7.6)				438,825	6.84 (4.05-10.81)	
Region							
Seoul, Kangwon	22 (9.3)				3,979,140	0.92 (0.58-1.39)	
Busan, Ulsan, Gyeongnam	29 (12.3)				1,959,444	2.47 (1.65-3.54)	
Daegu, Gyeonbuk	7 (3.0)				1,118,725	1.04 (0.42-2.15)	
Gyeonggi, Incheon	133 (56.4)				2,606,896	8.50 (7.12-10.08)	
Gwangju, Jeonla, Jeju	22 (9.3)				1,121,051	3.27 (2.05-4.95)	
Daejeon, Chungcheong	23 (9.7)				1,084,237	3.54 (2.24-5.30)	

*Physician reports include reports from occupational physicians, allergy and chest physicians, and regional work-related disease surveillance systems; [†]Estimated cases were calculated by the capture-recapture analyses by two reporting sources; [‡]Estimated average annual incidence rates were calculated with estimated cases.

nonsuspicious, but details of this testing were not provided by the reporting source (Table 1).

The number of allergy and chest clinics that reported at least 1 case was 16, and 8 of these clinics accounted for the vast majority of reports (118 [93.7%] of 126 cases). The number of occupational clinics that reported at least 1 case was 15, and 8 occupational clinics reported 41 of these cases (78.8% of 52) (Table 2).

The average annual incidence during the 6-year period was 3.31 per million workers. When stratified by sex, the average annual incidences were 3.78/million male workers and 2.58/million female workers. The incidence was highest in the 50-59 year age group at 7.74/million workers. By region, the incidence was highest in Gyeonggi/Incheon at 8.50/million workers, and lowest in Seoul and Gangwon at 0.92/million workers. The number of cases estimated by the capture-recapture method was 447 (95% CI: 353-541), and the corresponding average annual incidence of WRA was 6.28 (95% CI: 4.96-7.60) cases/million workers, approximately double the crude incidence (Table 3). By industry, the incidence was highest in the furniture and other instrument manufacturing industries at 67.62/million workers. By occupation, the incidence rate was highest in the craft and related trades at 17.75/million workers (Table 4).

Among the suspected causative agents of OA or triggering factors of WEA, isocyanates were the most frequent at 46.6%, followed by flour/grain (8.5%), metals (5.9%), reactive dyes (5.1%), and solvents (4.2%). The distribution of causal agents was not

significantly different between men and women for the 7 most frequently reported agents (Table 5).

During the study period, isocyanate-related asthma followed a decreasing trend ($P=0.002$). In terms of asthma sub-types, the frequency of sensitizer-induced OA also followed a decreasing trend ($P=0.008$), while that of WEA appeared to be increasing ($P=0.006$), but was based on data from a very small number of cases. While the number of cases reported by occupational physicians and regional surveillance systems steadily decreased, those reported by allergy and chest physicians remained relatively steady (Table 6).

DISCUSSION

The average WRA incidence of 3.31/million reported in our study was lower than those reported by surveillance systems in other countries, which ranged from 5-174/million workers.^{7,8,24-29} This difference suggests a lower prevalence of asthma in Korea than in other industrialized countries,^{1,3,30} and a lower proportion of WRA among adult asthmatics.¹² However, most of the available estimates from other industrialized countries are based on data from the 1990s. Since WRA surveillance in Korea began later than in other countries, direct comparison of rates should be performed with caution. In some countries (e.g. the UK and France), the number of WRA cases decreased during the 1990-2000s; possible reasons for the decrease being due to

Table 4. Crude and estimated average annual incidence of work-related asthma per million workers by industry and occupation - Korea, 2004-2009

	Total cases n (%)	Workers' compensation report	Physician report*	Estimated cases† (95% CI)	Number of employees	Crude average annual incidence rate (95% CI)	Estimated average annual incidence rate‡ (95% CI)
Study population	236 (100.0)	102	173	447 (353-541)	11,869,493	3.31 (2.90-3.76)	6.28 (4.96-7.60)
Industry [§]							
Manufacture of food & beverage (15)	21 (8.9)	5	16		224,403	15.60 (9.66-23.84)	
Manufacture of wood and pulp products (20-21)	8 (3.4)	3	7		97,925	13.62 (5.87-26.82)	
Manufacture of chemicals, rubber and plastics (24-25)	43 (18.2)	17	30		378,449	18.94 (13.71-25.51)	
Metal, ceramic, and machinery (22, 26-33)	25 (10.6)	13	16		1,667,334	2.50 (1.62-3.69)	
Vehicles and transport equipment (34-35)	42 (17.8)	20	32	60 (42-77)	389,054	17.99 (12.97-24.32)	25.49 (17.91-33.07)
Furniture and other instruments (36)	45 (19.1)	23	34	64 (45-82)	110,908	67.62 (49.32-90.48)	95.60 (68.30-122.90)
Construction (45-46)	12 (5.1)	3	10		809,992	2.47 (1.28-4.31)	
Services and trades (40, 50-93)	26 (9.7)	11	18		4,836,076	0.90 (0.59-1.04)	
Occupation							
0. Legislators, senior officials and managers	1 (0.4)	0	1		533,857	0.31 (0.01-1.74)	
1. Professionals	7 (3.0)	2	5		1,253,016	0.93 (0.37-1.92)	
2. Technicians and associated professionals	4 (1.7)	1	3		1,736,782	0.38 (0.10-0.98)	
3. Clerks	3 (1.3)	1	2		3,309,201	0.15 (0.03-0.44)	
4. Service workers	5 (2.1)	0	5		414,545	2.01 (0.65-4.69)	
5. Sales workers	1 (0.4)	1	1		264,436	0.63 (0.02-3.51)	
6. Skilled agricultural, forestry and fishery workers	1 (0.4)	1	0		17,844	9.34 (0.28-52.02)	
7. Craft and related trades workers	110 (46.6)	44	86	185 (136-235)	1,032,887	17.75 (14.59-21.39)	29.92 (21.92-37.92)
8. Plant workers, machine operators and assemblers	81 (34.3)	46	53	133 (96-169)	2,147,733	5.58 (4.43-6.94)	9.14 (6.63-11.65)
9. Elementary occupations	15 (6.4)	6	9		533,857	4.68 (2.90-3.76)	

*Physician reports include reports from occupational physicians, allergy and chest physicians, and regional work-related disease surveillance systems; †Estimated cases were calculated by the capture-recapture analyses by two reporting sources; ‡Estimated average annual incidence rates were calculated with estimated cases; §Industries classified according to the 8th Korean Standard Industrial Classification; ||Occupations classified according to the 5th Korean Standard Classification of Occupations.

reporting fatigue, changes in industrial structure, and substitution of hazardous materials from the workplace.^{31,32} Other possible reasons for the underestimation include the workers' unwillingness to report illness because of concerns about job loss,²⁴ lack of workers' compensation coverage among some workers who may be at high risk of developing WRA (e.g. self-employed and temporary workers are not covered, and may carry a high risk of developing WRA),³³ physicians' failure to ask about work-relatedness, and physicians' unwillingness to report to surveillance schemes even when work-relatedness is suspected.³⁴ Furthermore, the observed differences in WRA rates between countries arise not only from differences in reporting but also from differences in the distribution of industries and occupations.²⁶

The WRA incidence estimated by capture-recapture analysis was 6.28/million. Capture-recapture models allow the estimation of the true number of cases and the assessment of the completeness of the surveillance data. This methodology has

been used in a variety of public health areas.^{23,35} The NIOSH in the United States used capture-recapture methods and estimated that the "true" number of WRA cases was approximately 6- to 7-fold higher than the number reported using surveillance data.²⁶ In our study, the estimated "true" number of cases was approximately double the reported number.

Approximately 80.1% (n=189) of all reported WRA cases were found in the manufacturing sector, including furniture manufacturing, chemical manufacturing, vehicle manufacturing, and food and beverage manufacturing. The rates in these manufacturing industries were higher than those in almost all other industries. The WRA incidence was highest in the furniture manufacturing industry (67.62/million), likely due to the high rate of isocyanate use, which is the leading cause in the development of WRA.

Workers aged ≥ 50 years of age had higher rates of WRA compared to younger workers. This pattern has also been observed

Table 5. Causal agents* of work-related asthma by sex, Korea, 2004-2009

Agent	Total	Men	Women
Isocyanates	110 (46.6)	79 (48.2)	31 (43.1)
Flour/grain	20 (8.5)	12 (7.3)	8 (11.1)
Metals	14 (5.9)	9 (5.5)	5 (6.9)
Reactive dyes	12 (5.1)	11 (6.7)	1 (1.4)
Solvents	10 (4.2)	7 (4.3)	3 (4.2)
Pharmaceuticals	8 (3.4)	3 (1.8)	5 (6.9)
Wood dusts	8 (3.4)	5 (3.0)	3 (4.2)
Smoke, fumes	6 (2.5)	5 (3.0)	1 (1.4)
Cyanoacrylate	3 (1.3)	0 (0.0)	3 (4.2)
Synthetic glues	3 (1.3)	2 (1.2)	1 (1.4)
Persulphate	3 (1.3)	0 (0.0)	3 (4.2)
Paints	3 (1.3)	2 (1.2)	1 (1.4)
Irritant gases	3 (1.3)	3 (1.8)	0 (0.0)
Other dusts	3 (1.3)	3 (1.8)	0 (0.0)
Chemical compounds	3 (1.3)	2 (1.2)	1 (1.4)
Animal antigens	2 (0.8)	2 (1.2)	0 (0.0)
Plant antigens	1 (0.4)	1 (0.6)	0 (0.0)
Molds	2 (0.8)	2 (1.2)	0 (0.0)
Azodicarbonamide	2 (0.8)	2 (1.2)	0 (0.0)
Bleach	2 (0.8)	0 (0.0)	2 (2.8)
Metal-working fluids	2 (0.8)	2 (1.2)	0 (0.0)
Synthetic resins	1 (0.4)	1 (0.6)	0 (0.0)
Bisulfite salts	1 (0.4)	1 (0.6)	0 (0.0)
Phthalic anhydride	1 (0.4)	1 (0.6)	0 (0.0)
Colophony	1 (0.4)	0 (0.0)	1 (1.4)
Chocolate powder	1 (0.4)	0 (0.0)	1 (1.4)
Cold air	1 (0.4)	0 (0.6)	0 (0.0)
Unidentified	10 (4.2)	8 (4.9)	2 (2.8)
Total	236 (100.0)	164 (100.0)	72 (100.0)

*Cold air was not a causal agent, but an aggravating factor for one case with pre-existing asthma.

in previous studies^{8,24,29,36} and could be due to a combination of reasons. For example, older workers are more likely to have a longer duration of exposure to hazardous substances, and they may have a greater susceptibility to developing asthma. In addition, younger workers may find it easier to change jobs to avoid exposures, and older workers may delay reporting their asthma symptoms.^{24,26,37}

The rates of WRA in Korea differ substantially across regions within the country, ranging from 0.92-8.50/million workers. Regional differences were also found in France.²⁴ These findings may be due to regional differences in reporting, and in industrial composition.

As in other countries,^{7,8,25,27,38-40} the most common cause of WRA in Korea was exposure to isocyanates, but the proportion of WRA cases attributed to isocyanates in Korea (46.6%) was much higher than that in other countries (13.6%-23.1%). Possi-

ble reasons were that claims for compensation are generally approved whenever isocyanate is present at the workplace regardless of the actual WRA cause and reporting physicians are familiar with the processes leading to isocyanate exposure. The second most common cause of WRA in our study was grain dust, which was possibly due to a large number of WRA cases identified during an epidemiological investigation at a bakery.⁴¹ Approximately 5%-10% of bakery workers are thought to have WRA.⁴² Moreover, the actual number of cases of WRA caused by grain dust may have been much higher, considering that agriculture workers in small companies (<5 workers) and the self-employed are not eligible for workers' compensation in Korea.³³ Some new and emerging causes of WRA were also identified by the KOWAS. Examples include azodicarbonamide⁴³ (used as a plastic foaming agent) and cyanoacrylate⁴⁴ (used as an instant glue), both of which had not previously been observed to cause WRA in Korea.

The pattern of isocyanate exposure being the dominant cause of WRA in Korea tended to diminish over time. Factors responsible for this decrease may include recent increased awareness and recognition of other causes of WRA, and a true reduction in the incidence of isocyanate-induced WRA, a sensitizer-induced OA. Reductions in the incidence of isocyanate-induced WRA were also observed in France.³² Few cases of irritant-induced OA were identified by the KOWAS. This may be because an understanding of the role of respiratory irritants in the etiology of OA is too recent a phenomenon to be captured by the KOWAS data.⁴⁵

This analysis has several limitations. Although isocyanates were the most common cause of WRA, in some instances of isocyanate-caused WRA, an agent other than isocyanates may have caused the asthma. Second, the reported rates are likely to be underestimates. Many cases of WRA are never ascertained or reported. This is because many workers are not covered by workers' compensation, or because many physicians fail either to diagnose WRA or to report WRA to the KOWAS. Third, detailed information on the specific objective diagnostic tests that were used to assess the work-relatedness criteria were often not available to the KOWAS. In these instances, the KOWAS relied on the work-relatedness assessment made by the reporting source. Fourth, the specific causal agent of WRA could not be identified because objective tests on the specific agents were either not conducted or the test results were not available to the KOWAS. A similar lack of specificity is present in WRA reports from other countries.^{7,8,24,25,27-29}

The effectiveness of the KOWAS could be improved if it was supported by active and ongoing work-related disease surveillance schemes and occasional company-wide health evaluations. The latter, prompted by findings made during the course of our surveillance study, helped to identify many additional WRA cases in a bakery. After a sentinel case of baker's asthma from an industrial bakery was reported to the KOWAS in Octo-

Table 6. Distribution of work-related asthma (WRA) cases by sex, causal agent, WRA sub-type, and reporting source - Korea, 2004-2009

	2004	2005	2006	2007	2008	2009	P-value*
Total	40 (100.0)	52 (100.0)	35 (100.0)	58 (100.0)	25 (100.0)	26 (100.0)	
Female	11 (27.5)	14 (26.9)	12 (34.3)	19 (32.8)	5 (20.0)	11 (42.3)	0.568
Causal agent							
Isocyanates	26 (65.0)	24 (46.2)	20 (57.1)	23 (39.7)	10 (40.0)	7 (26.9)	0.002
Flour/grain	0 (0.0)	1 (1.9)	2 (5.7)	15 (25.9)	0 (0.0)	2 (7.7)	0.023
Metals	1 (2.5)	2 (3.8)	3 (8.6)	3 (5.2)	3 (12.0)	2 (7.7)	0.175
Reactive dyes	4 (10.0)	5 (9.6)	3 (8.6)	0 (0.0)	0 (0.0)	0 (0.0)	0.003
Solvents	0 (0.0)	2 (3.8)	2 (5.7)	6 (10.3)	0 (0.0)	0 (0.0)	0.727
Pharmaceuticals	0 (0.0)	1 (1.9)	0 (0.0)	3 (5.2)	2 (8.0)	2 (7.7)	0.021
Wood dust	3 (7.5)	1 (1.9)	3 (8.6)	0 (0.0)	0 (0.0)	1 (3.8)	0.185
WRA sub-type							
Sensitizer-induced OA	37 (92.5)	46 (88.5)	33 (94.3)	52 (89.7)	18 (72.0)	19 (73.1)	0.008
Irritant-induced OA	1 (2.5)	4 (7.7)	2 (5.7)	1 (1.7)	3 (12.0)	2 (7.7)	0.468
WEA	1 (2.5)	0 (0.0)	0 (0.0)	3 (5.2)	1 (4.0)	4 (15.4)	0.006
Reporting source [†]							
Compensation scheme	22 (55.0)	24 (46.2)	16 (45.7)	19 (32.8)	11 (44.0)	10 (38.5)	0.091
Allergy/chest physician	19 (47.5)	33 (63.5)	16 (45.7)	25 (43.1)	15 (60.0)	16 (61.5)	0.765
Regional surveillance [‡]	23 (57.5)	15 (28.8)	12 (34.3)	7 (12.1)	0 (0.0)	0 (0.0)	
Occupational physician	14 (35.0)	9 (17.3)	8 (22.9)	17 (29.3)	3 (12.0)	1 (3.8)	0.023

WRA, work-related asthma; OA, occupational asthma; WEA, work-exacerbated asthma.

*P-value by Cochran-Armitage trend test; [†]Total percentages may exceed 100 because of multiple reporting; [‡]P-value could not be calculated because reporting from the regional surveillance systems ceased after 2007.

ber 2005, a thorough epidemiological investigation was performed by the KOSHA in 2006-2007.⁴¹ As a result, 12 additional workers were diagnosed with baker's asthma and reported to the KOWAS. In other cases where the causal agents could not be identified, or their work-relatedness could not be established, the KOWAS findings prompted additional epidemiological investigations.^{46,47}

Before the KOWAS was established, the only method to estimate rates of WRA in Korea was by analyzing data from workers' compensation reports. However, many WRA patients do not apply for workers' compensation. The KOWAS scheme was designed to overcome this limitation. From 1997-2003, the number of cases of WRA from workers compensation ranged from 4-29. During the study period (2004-2009), the total number of WRA cases identified by the KOWAS was more than double the number of cases identified by the worker's compensation scheme alone. As a public health surveillance system, the objective of the KOWAS is not only to estimate the magnitude of WRA, but to also analyze WRA trends in Korea, to detect emerging causes of WRA, and to guide policy changes and workplace interventions in order to prevent WRA and promote worker health.

In conclusion, the incidence of WRA estimated from surveillance data was lower in Korea than in other countries, and the incidence varied according to industry, occupation, sex, and

region. Data provided jointly by workers' compensation schemes and physician reports are useful for determining the rates and causes of WRA in Korea.

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